Using supercritical carbon dioxide as a fracturing fluid

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Laboratory researchers have published a paper in *Applied Energy* examining opportunities and challenges to produce gas from tight shale formations using supercritical carbon dioxide (CO_2) as a fracturing fluid. The team used a combination of theory, modeling and experiments at multiple scales to analyze the benefits and drawbacks of using supercritical CO_2 as a working fluid for shale gas production. Industry and researchers are interested in non-aqueous working fluids due to the potential to increase production, reduce water requirements and to minimize environmental impacts.

Significance of the research

Hydraulic fracturing of shale formations in the United States has led to a domestic energy boom. The process of injecting a fluid—typically water—into a target formation at pressures high enough to fracture the rock, is performed to increase permeability and thereby increase production. Currently, water is the only fracturing fluid regularly used in large-scale commercial shale oil and gas production in the U.S. Concerns about the use of water (water-availability, treatment or disposal of contaminated flow-back water, induced seismicity, and the very small permeability of some rock formations) have led to investigation of non-aqueous fracturing fluids such as supercritical CO_2. Non-aqueous working fluids might enhance gas production and reduce environmental concerns compared with aqueous fluids.

The Laboratory research is part of an ongoing project to make the necessary measurements and develop models to compare different working models of hydraulic fracturing for shale gas and oil production. The publication presents an evaluation of the challenges and opportunities of the use of supercritical CO_2 as a fracturing fluid for shale gas production. Through a combination of methodologies, the researchers have determined that non-aqueous working fluids offer the potential to reduce the water use of shale gas and oil production and reduce environmental impacts, while also increasing hydrocarbon production.

Research achievements

The Laboratory team used a combination of experiments and modeling for the investigation. A first-of-a-kind high pressure and temperature microfluidic experiment in etched shale demonstrated that CO_2 efficiently sweeps through the rock and dissolves in the most common liquids present in the reservoirs, including water and hydrocarbons. The researchers also performed simulations using a novel reservoir-scale discrete fracture network (DFN) modeling approach that the Lab developed.

The paper suggested the following potential advantages of using supercritical CO_2:

- enhanced fracturing and fracture propagation due to more extensive and complex fracture networks when compared with water-based working fluids
- reduction of flow-blocking mechanisms
- increased desorption of methane adsorbed in organic-rich parts of the shale
- a reduction or elimination of the deep re-injection of flow-back water that has been linked to induced seismicity and other environmental concerns

The authors conclude that supercritical CO_2 might lead to substantially increased gas production while lowering environmental impacts. Moreover, if CO_2 is proven to be an effective fracturing fluid, then shale gas formations could become a major option for carbon sequestration of this greenhouse gas. However, the researchers identified challenges for the use of supercritical CO_2. These include costs and safety issues associated with handling large volumes of the fluid.

Lab research team

Researchers include Richard Middleton, Jeffrey Hyman, Qinjun Kang, Satish Karra and Hari Viswanathan, Bill Carey, Mark Porter, Joaquín Jiménez-Martínez and Robert Currier.

The Laboratory Research and Development (LDRD) program and the DOE Unconventional Fossil Energy Program managed by the National Energy Technology Laboratory's Strategic Center for Natural Gas and Oil funded different aspects of the work. The research supports the Laboratory's Energy Security mission area and the Information, Science, and Technology and the Materials for the Future science pillars through the development of means to evaluate working fluids for gas production from tight shale formations and for carbon sequestration of the greenhouse gas carbon dioxide.

Caption for image below: *Reservoir-scale modeling approach to obtain gas production curves through fracture drainage. The simulation tracked 100,000 particles.*